CONVOLUTIONAL NEURAL NETWORKS

BY SUNEESH JACOB

CONVOLUTIONAL NEURAL NETWORK

- Convolution
  - Kernel (Filter)
  - Stride
  - Padding
    - Zero
    - Same

CONVOLUTIONAL NEURAL NETWORK

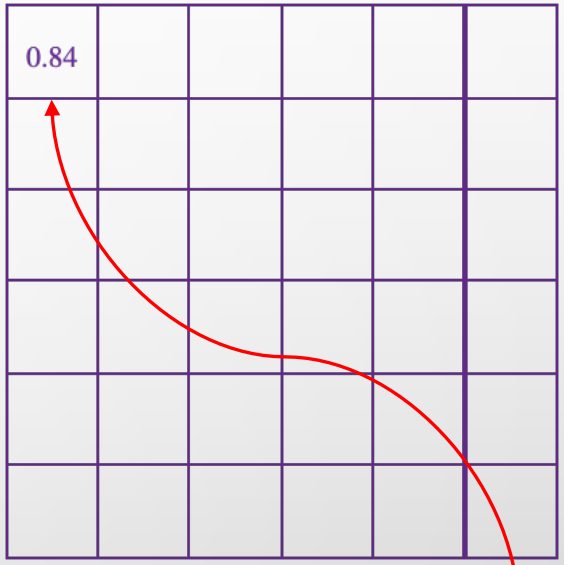
- Convolution
  - Kernel (Filter)

0.37	0.33	−0.76
−0.52	−0.65	0.19
−0.44	−0.03	−0.81

Stride: 1

$b = 0.89$

0.15	0.18	0.25	−0.5	0.45	−0.04	−0.73	−0.05
−0.25	−0.51	−0.65	−0.05	0.29	0	0.06	0.28
−0.24	0.51	−0.53	−0.15	0.08	−0.37	−0.25	−0.45
−0.7	−0.12	−0.22	0.08	−0.03	−0.1	−0.28	−0.16
−0.21	0.06	0.32	0.16	0.27	0	0.01	−0.22
0.16	0.29	−0.09	0.67	−0.75	0.37	0.11	0
0.08	0.2	−0.36	−0.51	−0.19	−0.89	−0.06	−0.19
0.29	−0.26	0.87	0.5	0.04	−0.49	0.04	0.24



$$z_{11} = \sigma(0.37\times0.15 + 0.33\times0.18 + (-0.76)\times0.25 + (-0.52)\times(-0.25) + (-0.65\times-0.51) + 0.19\times(-0.65) + (-0.44\times-0.24) + (-0.03\times0.51) + (-0.81)\times(-0.53) + 0.89) = 0.84$$

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0.84	0.88				

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$z_{12} = \sigma(0.37\times0.18 + 0.33\times0.25 + (-0.76)\times(-0.05) + (-0.52)\times(-0.51) + (-0.65\times-0.65) + 0.19\times(-0.05) + (-0.44\times0.51) + (-0.03\times-0.53) + (-0.81)\times(-0.15) + 0.89) = 0.88$

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0.84	0.88	0.75			

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Stride: 1

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0.79					

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Feature map

0.84	0.88	0.75	0.75	0.84	0.77
0.79	0.64	0.71	0.73	0.79	0.76
0.83	0.75	0.57	0.74	0.71	0.8
0.71	0.46	0.78	0.54	0.76	0.66
0.63	0.78	0.66	0.9	0.79	0.79
0.51	0.54	0.85	0.73	0.78	0.82

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$$\vdots$$
$$z_{66} = \sigma(0.37\times0.37 + 0.33\times0.11 + (-0.76)\times0 + (-0.52)\times(-0.89) + (-0.65\times-0.06) + 0.19\times(-0.19) + (-0.44\times-0.49) + (-0.03\times0.04) + (-0.81)\times0.24 + 0.89) = 0.82$$

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0.16	0.29	−0.09	0.67	−0.75	0.37	0.11	0
0.08	0.2	−0.36	−0.51	−0.19	−0.89	−0.06	−0.19
0.29	−0.26	0.87	0.5	0.04	−0.49	0.04	0.24

What happens when the stride is 2?

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  - Kernel (Filter)

0.37	0.33	−0.76
−0.52	−0.65	0.19
−0.44	−0.03	−0.81

Stride: 2

$b = 0.89$

0.15	0.18	0.25	−0.5	0.45	−0.04	−0.73	−0.05
−0.25	−0.51	−0.65	−0.05	0.29	0	0.06	0.28
−0.24	0.51	−0.53	−0.15	0.08	−0.37	−0.25	−0.45
−0.7	−0.12	−0.22	0.08	−0.03	−0.1	−0.28	−0.16
−0.21	0.06	0.32	0.16	0.27	0	0.01	−0.22
0.16	0.29	−0.09	0.67	−0.75	0.37	0.11	0
0.08	0.2	−0.36	−0.51	−0.19	−0.89	−0.06	−0.19
0.29	−0.26	0.87	0.5	0.04	−0.49	0.04	0.24

0.84		

$$z_{11} = \sigma(0.37\times0.15 + 0.33\times0.18 + (-0.76)\times0.25 + (-0.52)\times(-0.25) + (-0.65\times-0.51) + 0.19\times(-0.65) + (-0.44\times-0.24) + (-0.03\times0.51) + (-0.81)\times(-0.53) + 0.89) = 0.84$$

CONVOLUTIONAL NEURAL NETWORK

- Convolution
  - Kernel (Filter)

0.37	0.33	−0.76
−0.52	−0.65	0.19
−0.44	−0.03	−0.81

Stride: 2

$b = 0.89$

0.15	0.18	0.25	−0.5	0.45	−0.04	−0.73	−0.05
−0.25	−0.51	−0.65	−0.05	0.29	0	0.06	0.28
−0.24	0.51	−0.53	−0.15	0.08	−0.37	−0.25	−0.45
−0.7	−0.12	−0.22	0.08	−0.03	−0.1	−0.28	−0.16
−0.21	0.06	0.32	0.16	0.27	0	0.01	−0.22
0.16	0.29	−0.09	0.67	−0.75	0.37	0.11	0
0.08	0.2	−0.36	−0.51	−0.19	−0.89	−0.06	−0.19
0.29	−0.26	0.87	0.5	0.04	−0.49	0.04	0.24

0.84	0.75	

$$z_{11} = \sigma(0.37\times0.15 + 0.33\times0.18 + (-0.76)\times0.25 + (-0.52)\times(-0.25) + (-0.65\times-0.51) + 0.19\times(-0.65) + (-0.44\times-0.24) + (-0.03\times0.51) + (-0.81)\times(-0.53) + 0.89) = 0.84$$

$$z_{12} = \sigma(0.37\times0.25 + 0.33\times(-0.5) + (-0.76)\times0.45 + (-0.52)\times(-0.65) + (-0.65\times-0.05) + 0.19\times(0.29) + (-0.44\times-0.53) + (-0.03\times-0.15) + (-0.81)\times(0.08) + 0.89) = 0.75$$

CONVOLUTIONAL NEURAL NETWORK

- Convolution
  - Kernel (Filter)

0.37	0.33	−0.76
−0.52	−0.65	0.19
−0.44	−0.03	−0.81

Stride: 2

$b = 0.89$

0.15	0.18	0.25	−0.5	0.45	−0.04	−0.73	−0.05
−0.25	−0.51	−0.65	−0.05	0.29	0	0.06	0.28
−0.24	0.51	−0.53	−0.15	0.08	−0.37	−0.25	−0.45
−0.7	−0.12	−0.22	0.08	−0.03	−0.1	−0.28	−0.16
−0.21	0.06	0.32	0.16	0.27	0	0.01	−0.22
0.16	0.29	−0.09	0.67	−0.75	0.37	0.11	0
0.08	0.2	−0.36	−0.51	−0.19	−0.89	−0.06	−0.19
0.29	−0.26	0.87	0.5	0.04	−0.49	0.04	0.24

0.84	0.75	0.84

$$z_{11} = \sigma(0.37\times0.15 + 0.33\times0.18 + (-0.76)\times0.25 + (-0.52)\times(-0.25) + (-0.65\times-0.51) + 0.19\times(-0.65) + (-0.44\times-0.24) + (-0.03\times0.51) + (-0.81)\times(-0.53) + 0.89) = 0.84$$

$$z_{12} = \sigma(0.37\times0.25 + 0.33\times(-0.5) + (-0.76)\times0.45 + (-0.52)\times(-0.65) + (-0.65\times-0.05) + 0.19\times(0.29) + (-0.44\times-0.53) + (-0.03\times-0.15) + (-0.81)\times(0.08) + 0.89) = 0.75$$

$$z_{13} = \sigma(0.37\times0.45 + 0.33\times(-0.04) + (-0.76)\times(-0.73) + (-0.52)\times(0.29) + (-0.65\times0) + 0.19\times(0.06) + (-0.44\times0.08) + (-0.03\times(-0.37)) + (-0.81)\times(-0.25) + 0.89) = 0.84$$

CONVOLUTIONAL NEURAL NETWORK

- Convolution
  - Kernel (Filter)

0.37	0.33	−0.76
−0.52	−0.65	0.19
−0.44	−0.03	−0.81

Stride: 2

$b = 0.89$

0.15	0.18	0.25	−0.5	0.45	−0.04	−0.73	−0.05
−0.25	−0.51	−0.65	−0.05	0.29	0	0.06	0.28
−0.24	0.51	−0.53	−0.15	0.08	−0.37	−0.25	−0.45
−0.7	−0.12	−0.22	0.08	−0.03	−0.1	−0.28	−0.16
−0.21	0.06	0.32	0.16	0.27	0	0.01	−0.22
0.16	0.29	−0.09	0.67	−0.75	0.37	0.11	0
0.08	0.2	−0.36	−0.51	−0.19	−0.89	−0.06	−0.19
0.29	−0.26	0.87	0.5	0.04	−0.49	0.04	0.24

0.84	0.75	0.84
0.83		

$$z_{11} = \sigma(0.37\times0.15 + 0.33\times0.18 + (-0.76)\times0.25 + (-0.52)\times(-0.25) + (-0.65\times-0.51) + 0.19\times(-0.65) + (-0.44\times-0.24) + (-0.03\times0.51) + (-0.81)\times(-0.53) + 0.89) = 0.84$$

$$z_{12} = \sigma(0.37\times0.25 + 0.33\times(-0.5) + (-0.76)\times0.45 + (-0.52)\times(-0.65) + (-0.65\times-0.05) + 0.19\times(0.29) + (-0.44\times-0.53) + (-0.03\times-0.15) + (-0.81)\times(0.08) + 0.89) = 0.75$$

$$z_{13} = \sigma(0.37\times0.45 + 0.33\times(-0.04) + (-0.76)\times(-0.73) + (-0.52)\times(0.29) + (-0.65\times0) + 0.19\times(0.06) + (-0.44\times0.08) + (-0.03\times(-0.37)) + (-0.81)\times(-0.25) + 0.89) = 0.84$$

$$z_{21} = \sigma(0.37\times0.15 + 0.33\times0.18 + (-0.76)\times0.25 + (-0.52)\times(-0.25) + (-0.65\times-0.51) + 0.19\times(-0.65) + (-0.44\times-0.24) + (-0.03\times0.51) + (-0.81)\times(-0.53) + 0.89) = 0.79$$

CONVOLUTIONAL NEURAL NETWORK

- Convolution
  - Kernel (Filter)

0.37	0.33	−0.76
−0.52	−0.65	0.19
−0.44	−0.03	−0.81

Stride: 2

$b = 0.89$

0.15	0.18	0.25	−0.5	0.45	−0.04	−0.73	−0.05
−0.25	−0.51	−0.65	−0.05	0.29	0	0.06	0.28
−0.24	0.51	−0.53	−0.15	0.08	−0.37	−0.25	−0.45
−0.7	−0.12	−0.22	0.08	−0.03	−0.1	−0.28	−0.16
−0.21	0.06	0.32	0.16	0.27	0	0.01	−0.22
0.16	0.29	−0.09	0.67	−0.75	0.37	0.11	0
0.08	0.2	−0.36	−0.51	−0.19	−0.89	−0.06	−0.19
0.29	−0.26	0.87	0.5	0.04	−0.49	0.04	0.24

Feature map

0.84	0.75	0.84
0.83	0.57	0.71
0.63	0.66	0.79

$$z_{11} = \sigma(0.37\times0.15 + 0.33\times0.18 + (-0.76)\times0.25 + (-0.52)\times(-0.25) + (-0.65\times-0.51) + 0.19\times(-0.65) + (-0.44\times-0.24) + (-0.03\times0.51) + (-0.81)\times(-0.53) + 0.89) = 0.84$$

$$z_{12} = \sigma(0.37\times0.25 + 0.33\times(-0.5) + (-0.76)\times0.45 + (-0.52)\times(-0.65) + (-0.65\times-0.05) + 0.19\times(0.29) + (-0.44\times-0.53) + (-0.03\times-0.15) + (-0.81)\times(0.08) + 0.89) = 0.75$$

$$z_{13} = \sigma(0.37\times0.45 + 0.33\times(-0.04) + (-0.76)\times(-0.73) + (-0.52)\times(0.29) + (-0.65\times0) + 0.19\times(0.06) + (-0.44\times0.08) + (-0.03\times(-0.37)) + (-0.81)\times(-0.25) + 0.89) = 0.84$$

$$z_{21} = \sigma(0.37\times0.15 + 0.33\times0.18 + (-0.76)\times0.25 + (-0.52)\times(-0.25) + (-0.65\times-0.51) + 0.19\times(-0.65) + (-0.44\times-0.24) + (-0.03\times0.51) + (-0.81)\times(-0.53) + 0.89) = 0.79$$

$$\vdots$$

$$z_{33} = \sigma(0.37\times0.37 + 0.33\times0.11 + (-0.76)\times0 + (-0.52)\times(-0.89) + (-0.65\times-0.06) + 0.19\times(-0.19) + (-0.44\times-0.49) + (-0.03\times0.04) + (-0.81)\times0.24 + 0.89) = 0.82$$

PADDING

- Padding is used to preserve the dimensions of input image in the feature map
  - The input image before convolution and the feature map after convolution would have the same size
- Types of padding:
  - Same padding
  - Zero padding
- Padding with even-sized kernels
  - Non-symmetric padding needs to be used for even-sized kernels
  - This is one reason why odd-sized kernels are preferred

PADDING

0.15	0.18	0.25	−0.5	0.45	−0.04	−0.73	−0.05
−0.25	−0.51	−0.65	−0.05	0.29	0	0.06	0.28
−0.24	0.51	−0.53	−0.15	0.08	−0.37	−0.25	−0.45
−0.7	−0.12	−0.22	0.08	−0.03	−0.1	−0.28	−0.16
−0.21	0.06	0.32	0.16	0.27	0	0.01	−0.22
0.16	0.29	−0.09	0.67	−0.75	0.37	0.11	0
0.08	0.2	−0.36	−0.51	−0.19	−0.89	−0.06	−0.19
0.29	−0.26	0.87	0.5	0.04	−0.49	0.04	0.24

Zero padding

0	0	0	0	0	0	0	0	0	0
0	0.15	0.18	0.25	−0.5	0.45	−0.04	−0.73	−0.05	0
0	−0.25	−0.51	−0.65	−0.05	0.29	0	0.06	0.28	0
0	−0.24	0.51	−0.53	−0.15	0.08	−0.37	−0.25	−0.45	0
0	−0.7	−0.12	−0.22	0.08	−0.03	−0.1	−0.28	−0.16	0
0	−0.21	0.06	0.32	0.16	0.27	0	0.01	−0.22	0
0	0.16	0.29	−0.09	0.67	−0.75	0.37	0.11	0	0
0	0.08	0.2	−0.36	−0.51	−0.19	−0.89	−0.06	−0.19	0
0	0.29	−0.26	0.87	0.5	0.04	−0.49	0.04	0.24	0
0	0	0	0	0	0	0	0	0	0

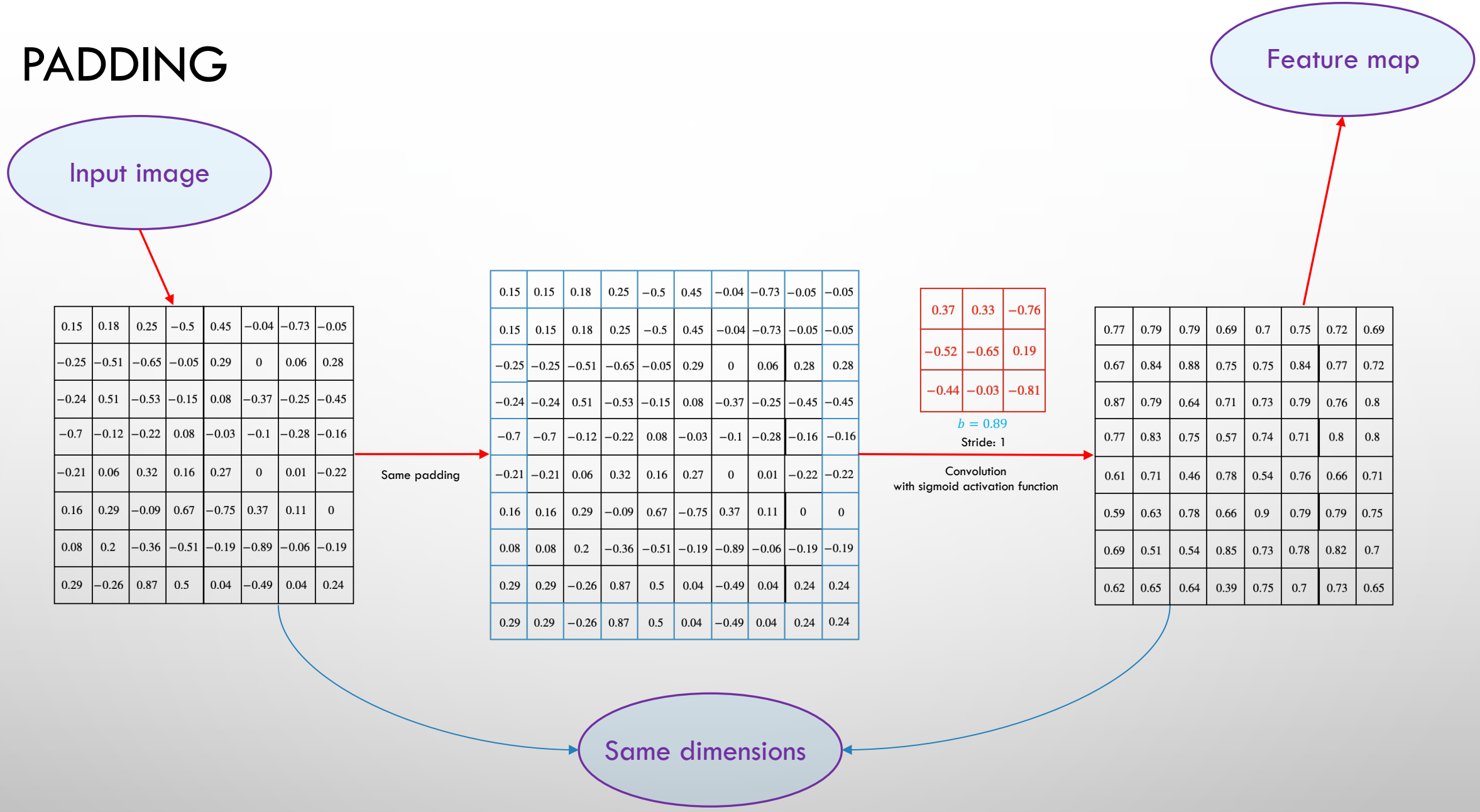
PADDING

0.15	0.18	0.25	−0.5	0.45	−0.04	−0.73	−0.05
−0.25	−0.51	−0.65	−0.05	0.29	0	0.06	0.28
−0.24	0.51	−0.53	−0.15	0.08	−0.37	−0.25	−0.45
−0.7	−0.12	−0.22	0.08	−0.03	−0.1	−0.28	−0.16
−0.21	0.06	0.32	0.16	0.27	0	0.01	−0.22
0.16	0.29	−0.09	0.67	−0.75	0.37	0.11	0
0.08	0.2	−0.36	−0.51	−0.19	−0.89	−0.06	−0.19
0.29	−0.26	0.87	0.5	0.04	−0.49	0.04	0.24

Same padding

0.15	0.15	0.18	0.25	−0.5	0.45	−0.04	−0.73	−0.05	−0.05
0.15	0.15	0.18	0.25	−0.5	0.45	−0.04	−0.73	−0.05	−0.05
−0.25	−0.25	−0.51	−0.65	−0.05	0.29	0	0.06	0.28	0.28
−0.24	−0.24	0.51	−0.53	−0.15	0.08	−0.37	−0.25	−0.45	−0.45
−0.7	−0.7	−0.12	−0.22	0.08	−0.03	−0.1	−0.28	−0.16	−0.16
−0.21	−0.21	0.06	0.32	0.16	0.27	0	0.01	−0.22	−0.22
0.16	0.16	0.29	−0.09	0.67	−0.75	0.37	0.11	0	0
0.08	0.08	0.2	−0.36	−0.51	−0.19	−0.89	−0.06	−0.19	−0.19
0.29	0.29	−0.26	0.87	0.5	0.04	−0.49	0.04	0.24	0.24
0.29	0.29	−0.26	0.87	0.5	0.04	−0.49	0.04	0.24	0.24

PADDING


Input image
Feature map
0.15 0.18 0.25 −0.5 0.45 −0.04 −0.73 −0.05
−0.25 −0.51 −0.65 −0.05 0.29 0 0.06 0.28
−0.24 0.51 −0.53 −0.15 0.08 −0.37 −0.25 −0.45
−0.7 −0.12 −0.22 0.08 −0.03 −0.1 −0.28 −0.16
−0.21 0.06 0.32 0.16 0.27 0 0.01 −0.22
0.16 0.29 −0.09 0.67 −0.75 0.37 0.11 0
0.08 0.2 −0.36 −0.51 −0.19 −0.89 −0.06 −0.19
0.29 −0.26 0.87 0.5 0.04 −0.49 0.04 0.24
Same padding
0.15 0.15 0.18 0.25 −0.5 0.45 −0.04 −0.73 −0.05 −0.05
0.15 0.15 0.18 0.25 −0.5 0.45 −0.04 −0.73 −0.05 −0.05
−0.25 −0.25 −0.51 −0.65 −0.05 0.29 0 0.06 0.28 0.28
−0.24 −0.24 0.51 −0.53 −0.15 0.08 −0.37 −0.25 −0.45 −0.45
−0.7 −0.7 −0.12 −0.22 0.08 −0.03 −0.1 −0.28 −0.16 −0.16
−0.21 −0.21 0.06 0.32 0.16 0.27 0 0.01 −0.22 −0.22
0.16 0.16 0.29 −0.09 0.67 −0.75 0.37 0.11 0 0
0.08 0.08 0.2 −0.36 −0.51 −0.19 −0.89 −0.06 −0.19 −0.19
0.29 0.29 −0.26 0.87 0.5 0.04 −0.49 0.04 0.24 0.24
0.29 0.29 −0.26 0.87 0.5 0.04 −0.49 0.04 0.24 0.24
0.37 0.33 −0.76
−0.52 −0.65 0.19
−0.44 −0.03 −0.81
b = 0.89
Stride: 1
Convolution
with sigmoid activation function
0.77 0.79 0.79 0.69 0.7 0.75 0.72 0.69
0.67 0.84 0.88 0.75 0.75 0.84 0.77 0.72
0.87 0.79 0.64 0.71 0.73 0.79 0.76 0.8
0.77 0.83 0.75 0.57 0.74 0.71 0.8 0.8
0.61 0.71 0.46 0.78 0.54 0.76 0.66 0.71
0.59 0.63 0.78 0.66 0.9 0.79 0.79 0.75
0.69 0.51 0.54 0.85 0.73 0.78 0.82 0.7
0.62 0.65 0.64 0.39 0.75 0.7 0.73 0.65
Same dimensions

MAX POOLING

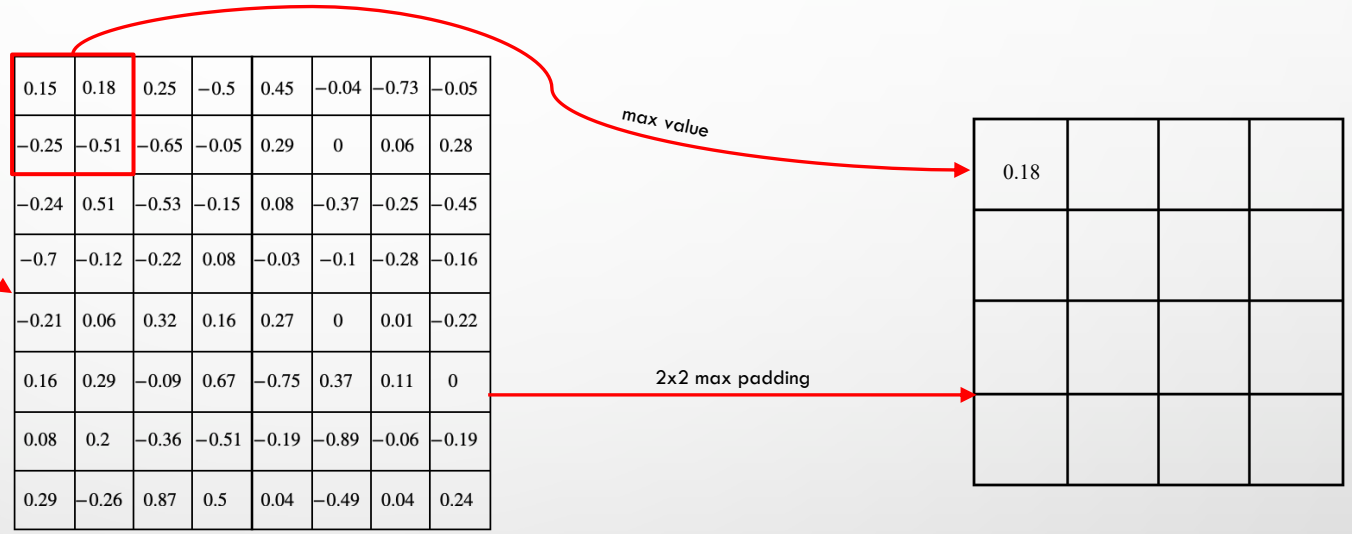
- Pooling is used to reduce the spatial dimensions, which can help in
  - Reduction in the number of parameters
  - Being less prone to overfitting
- Commonly used pooling types:
  - Max pooling
  - Avg pooling

MAX POOLING

Feature map before pooling

2x2 max pooling:

The maximum value of each 2x2 block is computed

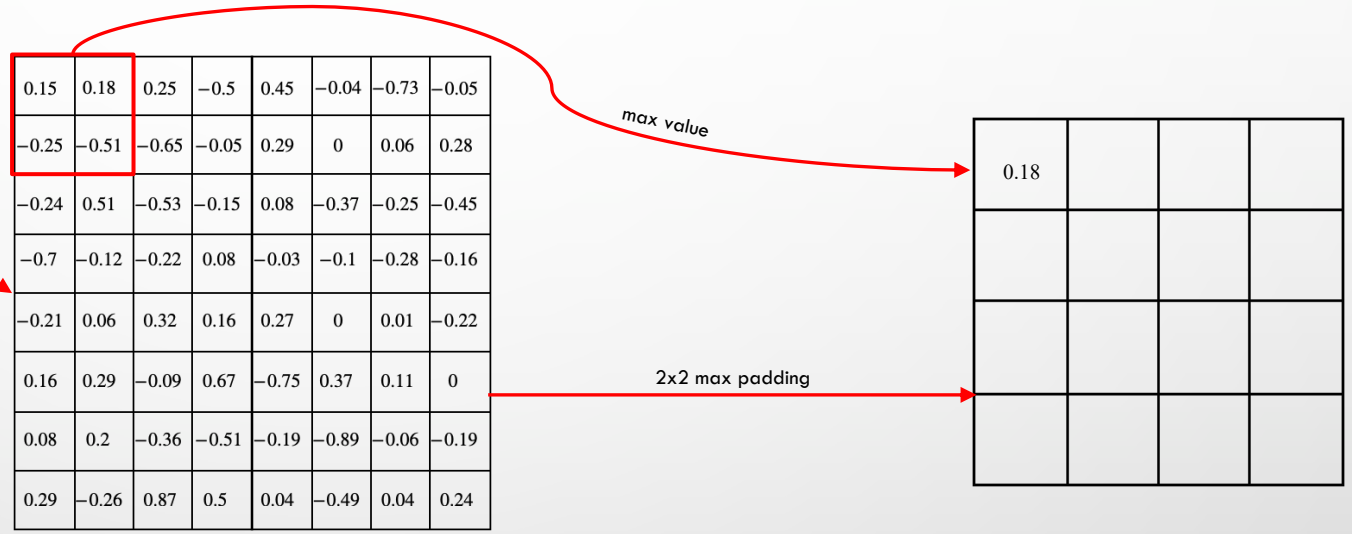


MAX POOLING

Feature map before pooling

2x2 max pooling:

The maximum value of each 2x2 block is computed

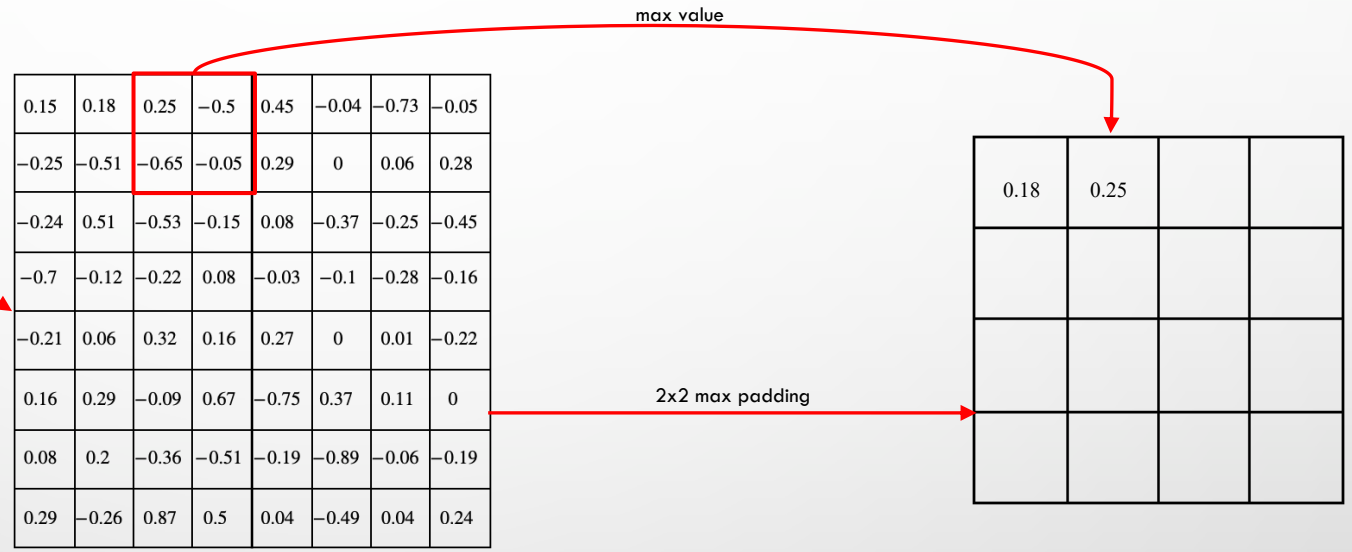


MAX POOLING

Feature map before pooling

2x2 max pooling:

The maximum value of each 2x2 block is computed

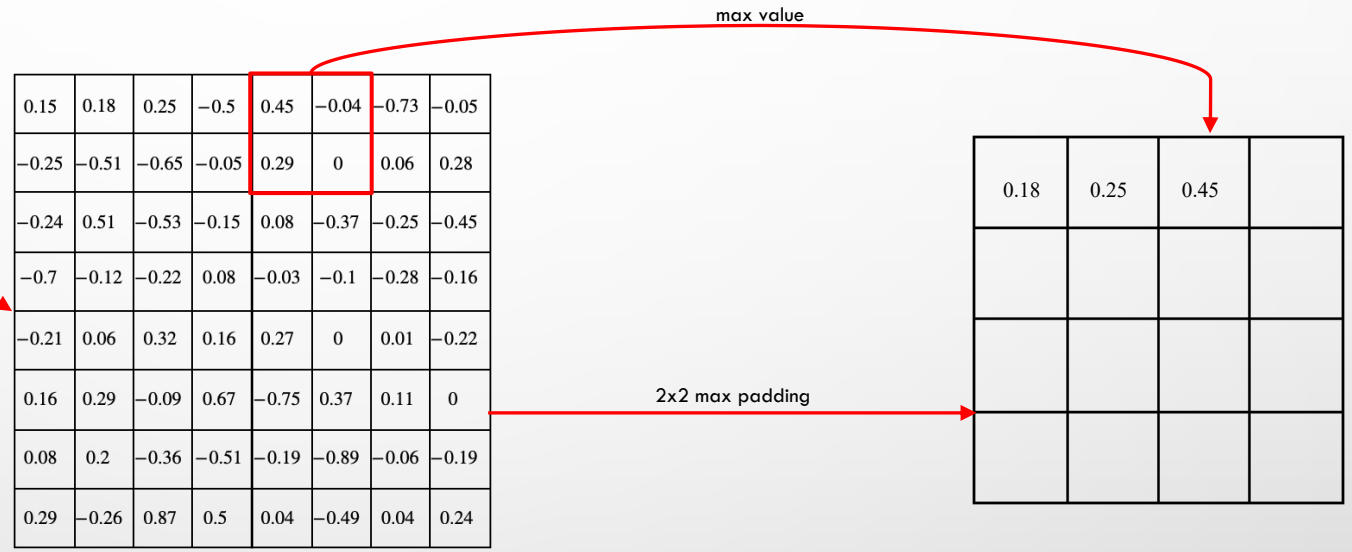


MAX POOLING

Feature map before pooling

2x2 max pooling:

The maximum value of each 2x2 block is computed

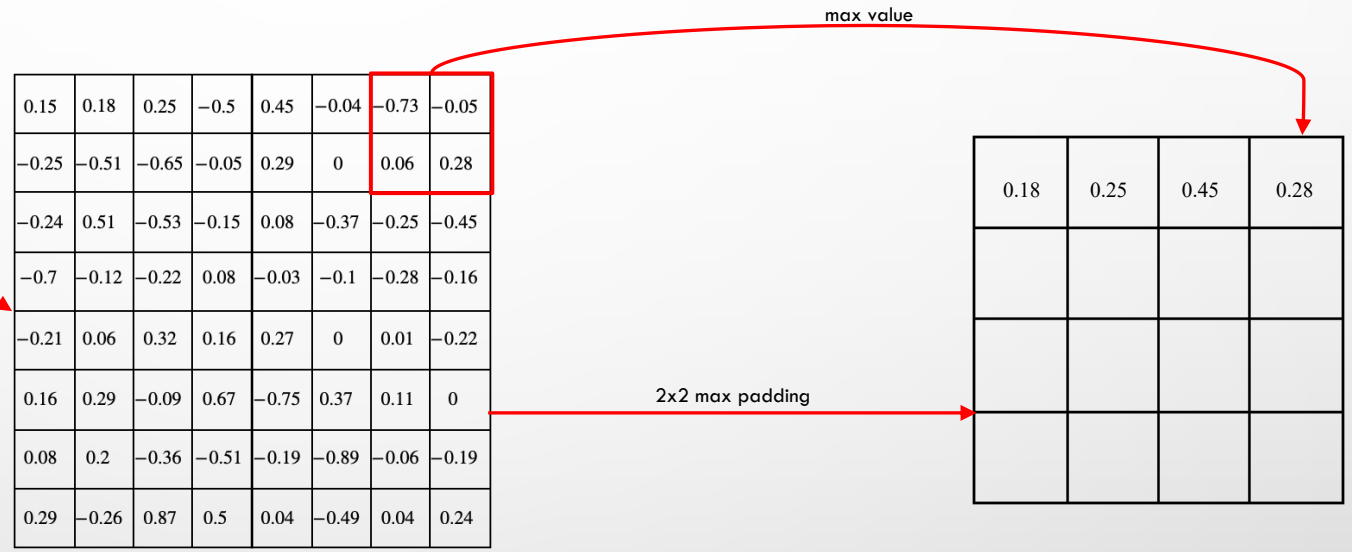


MAX POOLING

Feature map before pooling

2x2 max pooling:

The maximum value of each 2x2 block is computed

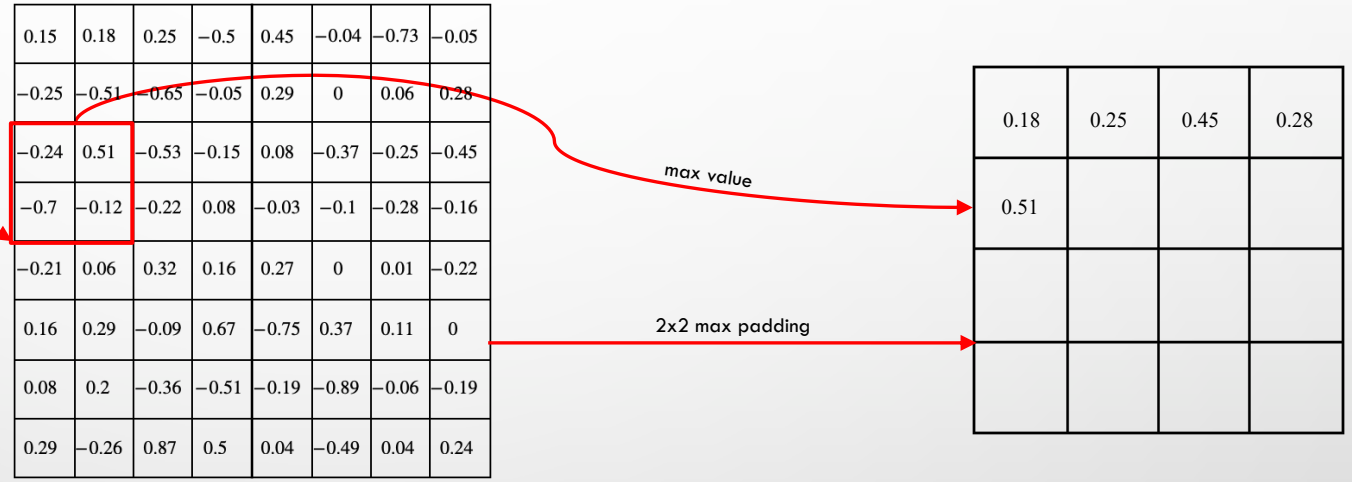


MAX POOLING

Feature map
before pooling

2x2 max pooling:

The maximum value of each 2x2 block is computed

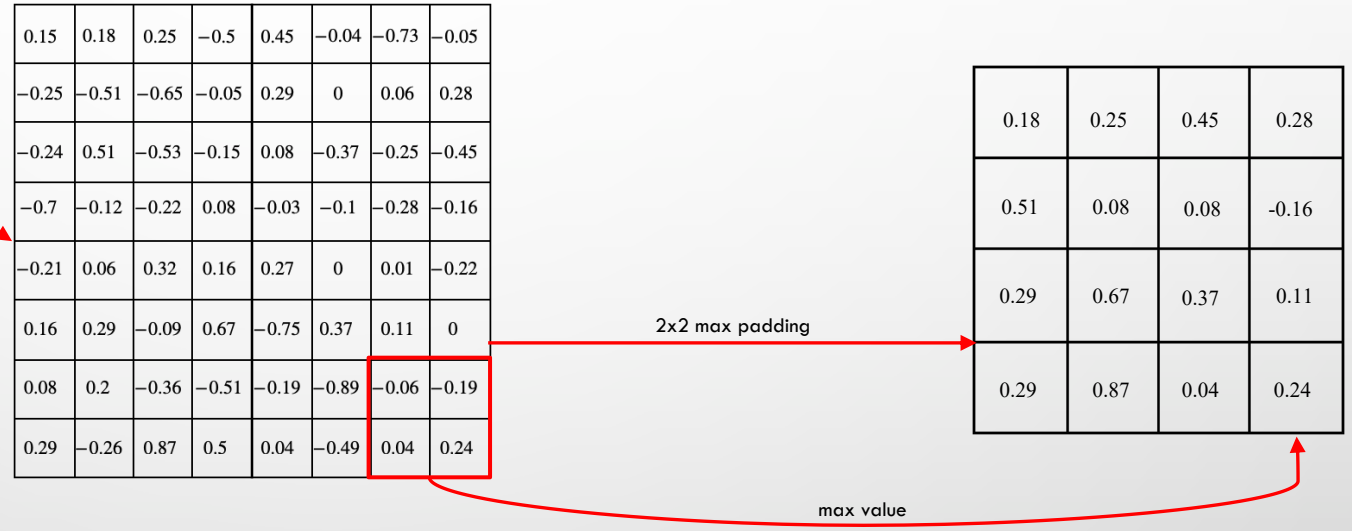


MAX POOLING

Feature map before pooling

2x2 max pooling:

The maximum value of each 2x2 block is computed



MAX POOLING

Feature map before pooling

2x2 max pooling:

The maximum value of each 2x2 block is computed

0.15	0.18	0.25	−0.5	0.45	−0.04	−0.73	−0.05
−0.25	−0.51	−0.65	−0.05	0.29	0	0.06	0.28
−0.24	0.51	−0.53	−0.15	0.08	−0.37	−0.25	−0.45
−0.7	−0.12	−0.22	0.08	−0.03	−0.1	−0.28	−0.16
−0.21	0.06	0.32	0.16	0.27	0	0.01	−0.22
0.16	0.29	−0.09	0.67	−0.75	0.37	0.11	0
0.08	0.2	−0.36	−0.51	−0.19	−0.89	−0.06	−0.19
0.29	−0.26	0.87	0.5	0.04	−0.49	0.04	0.24

2x2 max padding

0.18	0.25	0.45	0.28
0.51	0.08	0.08	-0.16
0.29	0.67	0.37	0.11
0.29	0.87	0.04	0.24

Feature map after pooling

MAX POOLING

Feature map before pooling

Avg pooling:

In average pooling the average value is computed instead of the maximum value

0.15	0.18	0.25	−0.5	0.45	−0.04	−0.73	−0.05
−0.25	−0.51	−0.65	−0.05	0.29	0	0.06	0.28
−0.24	0.51	−0.53	−0.15	0.08	−0.37	−0.25	−0.45
−0.7	−0.12	−0.22	0.08	−0.03	−0.1	−0.28	−0.16
−0.21	0.06	0.32	0.16	0.27	0	0.01	−0.22
0.16	0.29	−0.09	0.67	−0.75	0.37	0.11	0
0.08	0.2	−0.36	−0.51	−0.19	−0.89	−0.06	−0.19
0.29	−0.26	0.87	0.5	0.04	−0.49	0.04	0.24

2x2 avg padding

-0.11	-0.24	0.18	-0.11
-0.14	-0.2	-0.1	-0.28
0.08	0.26	-0.03	-0.02
0.08	0.12	-0.38	0.01

Feature map after pooling